ORDNANCE AND EXPLOSIVES COST-EFFECTIVENESS

RISK TOOL (OECert)

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ABSTRACT

A mathematical/engineering risk model has been developed by the U.S. Army Corps of Engineers and QuantiTech, Inc. for use in the defining of Ordnance and Explosives (OE) risk at Formerly Used Defense Sites (FUDS). The model uses several factors at a site (density of ordnance, type of ordnance, terrain features, population density, and many others) to determine the risk to public safety at the site. The model uses many of these same factors, as well as other factors to develop rough order of magnitude life cycle costs for the site. The model will allow the Government to develop a prioritized work list for the FUD sites, as well as to perform prioritized work between different sub-sites of a site. The model will also assist the decision maker in performing cost/benefit tradeoffs. The prioritization list will be used to ensure that the work that will reduce public risk the most for each dollar spent will be performed first. The model can also be used to determine the inherent risk at a site and can be used to determine when a site has been remediated to some previously specified level.

1.0 INTRODUCTION

The cost-effective remediation of sites which have been contaminated by Ordnance and Explosives is an elusive goal. The U.S. Army Engineer Division, Huntsville, in its role as OE Mandatory Center of Expertise and Design Center, has taken on the difficult task of formulating a quantitative risk tool to calculate the amount of risk reduction that can be achiever per dollar spent on OE site remediation. This tool, developed by QuantiTech, Inc. is the OE Cost Effectiveness Risk Tool (OECert). The model facilitates cost planning and aids in the formulation of remediation standards for all OE contaminated sites. The following sections provide a general overview of each of the modules, addressing background, methodology, data requirements, and model output products.

The OECert methodology is built around the exposure of the public to risk and the life cycle cost of the contaminated site through the phases of pre-remediation, remediation and post-remediation. Site assessment must precede any meaningful assessment of cost-effectiveness. The factors which drive cost-effectiveness are summarized in Figure 1. An important characteristic of OECert is the explicit integration of demographics with the characteristics which define the degree of contamination.

OECert prioritizes sites based on risk, cost, or cost-effectiveness ration. Effectiveness is measured by the risk reduction that can be obtained through remediation of a site. As shown in Figure 1, cost and risk reduction are dependent on a large number of variables. Cost for prioritization purposes, is measured in constant year dollars and includes the direct and indirect cost of remediation. The following summary explains how risk and cost are estimated, as well as how the cost-effectiveness ratio is calculated.

2.0 RISK ESTIMATION

A widely accepted definition of risk states that risk is equal to the product of the probability of an event occurring and the consequences of that event. This parallels the estimation approach used in OECert. An event is defined as the exposure by one member of the

public to at least one ordnance item. The consequence of this event is defined as the relative hazard associated with the OE located on the site. Hazard subjectively combines both the sensitivity of the ordnance and the consequences of the explosion.

The expected number of exposures to ordnance at a site is a function of the number of people entering the site, the activities they are performing, and the amount, type and visibility of ordnance contamination at the site.

For each activity occurring at a site, the expected number of exposures for a single individual performing that activity is determined based on the area covered by the individual, the OE contamination density, and the surface/subsurface distribution of the OE. Next, the expected number of participants in that activity for the particular site is calculated using the local demographics, activity participation rates and percentages, and the presence/absence of "competing" sites to perform the activity. These values are calculated and summed for all activities occurring in the site, yielding a total expected number of exposures. Risk then is calculated as the product of the expected exposures and the hazard factor for the OE contamination at the site. The fundamental risk equation for dispersed areas and their associated activities is summarized in Figure 2.

The amount of unexploded ordnance (UXO) contamination at a site may be described in terms of density or area and visibility of contamination. If the ordnance is spread over a relative large geographic area (i.e. dispersed sites), density (expressed as the number of UXO items per unit area) is used to describe the extent of ordnance contamination. Intuitively, the higher the density, the higher the risk of exposure. If the ordnance is confined to a relatively well defined area (i.e. localized sites), the two dimensional area containing the ordnance or line of sight surrounding the contaminated area is the measure that describes the extent of contamination. It is assumed that the larger the area the hazard occupies, or the more visible the hazard is, the higher the risk of public exposure.

The type of ordnance contamination at a site may be classified as one of eleven categories. These categories were identified by UXO professionals experienced in the handling and disposal of UXO and are as follows: dispersed UXO; dispersed UXO with special fuzing mechanisms; dispersed UXO with a charge of white phosphorus; dispersed controlled chemical biological or radiological weapons; localized armed UXO; localized unarmed UXO; explosives and materiel; propellants and pyrotechnics; non-controlled chemicals; bulk white phosphorus; localized controlled chemical, biological, and radiological weapons. Each of these ordnance categories has two relative hazard factors associated with it. These relative values describe the consequence of an ordnance item detonating and the sensitivity to detonation of the ordnance in each hazard classification.

3.0 COST ESTIMATION

A site's life-cycle is made up of three parts: pre-remediation, remediation and post-remediation. Cost estimates for these phases and the sum of these estimates provides a total site life cycle cost estimate.

Pre-remediation is the time period beginning when the site is identified and placed on the list of sites to be prioritized, and ending when remediation begins. Costs associated with this phase include any personnel, equipment, and material costs incurred during activities, such as feasibility studies, engineering evaluations, and site planning that take place to facilitate the site being prioritized and/or remediated.

Remediation is the time period when the physical site clean-up occurs. Cost associated with this phase include all personnel, equipment and material costs directly or indirectly related to the actual clean-up of ordnance contamination at the site. Remediation is expected to be the most cost intensive phase of the site life-cycle.

Post-remediation is the time period beginning when the site remediation effort ends and ending at the end of the analysis period. The total site life-cycle is assumed to be 30 years. Post-remediation under this assumption would be 30 years minus the number of years required for pre-remediation and remediation. Costs associated with this phase include any personnel, equipment, and material costs relating to activities required to limit public entry to the site (i.e. fence maintenance, guards, etc.). If the site is completely turned over for public use after remediation, there will be no post remediation cost associated with the site.

The cost module uses a combination of all four widely accepted cost-estimating methods depending on the data available. This combination of methods takes place within a framework of a "bottoms-up" work breakdown structure. The four methods are parametrics, engineering (bottoms-up), analogies, and expert opinion. Parametric estimates are those that apply quantitative methods to arrive at estimating relationships between cost elements. The expected evolution of OECert cost methodology is from parametric, through analogous, to bottoms-up. For example, by gathering actual contract data and applying regression analysis, a percentage can be applied to remediation clearance time to arrive at quality assurance time. The engineering, or bottoms-up approach, estimates at a piece part level and requires a great deal of experience in the activities being estimated. Analogies are costs that are estimated using actual costs from programs based on similarities that characterize the programs. Often, with analogies, complexity factors are used to adjust the cost upward or downward to account for the differences between technical considerations. Expert opinion estimates are judgments expressed by those with education and experience in the particular area being estimated.

Currently, the cost module's estimates are built on actual data collected at Mission Trails/Tierrasanta and Raritan sites and data from the OE-CWM Generic Cost Estimate. For prioritization and cost planning purposes, a database is being developed to supplement and enhance the previously gathered data. This database will provide consistency for studies, analyses, and budget and planning exercises and result in the reduction of cost analysis subjectivity.

Cost data is available to build the database. The data requirements include actual contract cost data, interviewing remediation participants and experts, analysis of data, and making provisions for cost feedback over time.

The model output for the cost module consists of a series of reports and briefing charts that summarize life-cycle cost. These reports are arranged by pre-remediation, remediation, post-remediation, and cost of no remediation. Reports are available to meet the various needs of the budgeting exercises, trade studies, and various other analyses. Within three life cycle elements, the work breakdown structure is employed to show costs at the lower levels. The cost module also shows costs either held constant or adjusted for inflation (escalated) and calculates both present and future values for the purpose of economic analyses dealing with the time value of money and alternate investment strategies.

4.0 COST-EFFECTIVENESS MEASURE

The prioritization of sites is based on a calculated cost-effectiveness ratio for each site. The cost-effectiveness measure compares delta risk to delta cost for each site. Delta risk is the difference between the estimated level of risk associated with the site before remediation occurs and the risk level established as the remediation standard. Delta cost is the difference between the life-cycle cost including remediation and the life cycle cost with no remediation phase included. The ratio resulting from these calculations gives the amount of expected risk reduction per dollar spent at the site under analysis.

5.0 DATA REQUIREMENTS

The data required to execute OECert can be placed into four broad categories: demographic data, parametric data, expert opinion data, and site assessment data. Data categories and sources gathered thus far are presented in tabular form. Data values that currently are nominal have potential data sources listed.

Demographic data includes, population totals, activity participation rates, gross and new construction building permit totals, average construction site sizes, surveying activity totals, and state and national park totals. These data values, with the exception of construction site size, are used in the calculation of the potential number of entrants to a contaminated site. Construction site size is used in the calculation of subsurface risk area.

Population totals are collected by count or city and are broken down into nine age categories. Activity participation rate data is broken down into the same nine age categories and is based on national participation statistics. Building permits are collected at the city and county level. Surveying activity is a nominal value based on local information and uses the number of "new" building permits issued. "New" construction is assumed to be all building not related to renovation, alteration, or addition. The number of state and national parks is collected on a state by state basis, but is implemented at the regional level. Table 1 summarizes the demographic data sources.

The parametric data set consists of the parameters needed to describe an individual's participation in identified activities. These parameters are: subsurface area covered by an individual, path width of an individual, an individual's activity participation time, an individual's velocity while performing an activity, and velocity degradation resulting rom the terrain conditions. Not all parameters are applicable to all activities. The values are used in the calculation of the area an individual covers while at a site. Table 2 presents the current parametric data requirements, sources for "hard" numbers, and proposed sources for nominal values.

Expert opinion data requirements consist of hazard factors elicited from UXO/EOD professionals through application of the Analytic Hierarchy Process (AHP) developed by T.L. Saaty of the University of Pittsburgh. THE AHP is an analytic technique that requires subject matter experts to compare the importance, in this case, sensitivity and consequence, of one ordnance item to another on a 1 to 9 scale of absolute numbers, 1 indicating equal importance and 9 indicating absolute superiority of one item to the other. A team of UXO safety professionals from the Corps of Engineers, Huntsville Division, participated in an AHP session and their input became the basis for the hazard classification. The hazard factor is the product of the sensitivity factor times the consequence factor. These factors have been adjusted to a scale from 1 to 100 for ease of application and presentation purposes. Table 3 lists the eleven hazard classifications along with their respective hazard factor values.

Table 1. Demographic Data Sources

Data Required	Source
Population Totals	United States Census Bureau 1990 CD ROM
Activity Participation Rates	American Sports Data Inc. American Sports Analysis 1992 Summary Report
Building Permits	United States Census Bureau Construction Statistics 1988-1992
Surveying Activities	Local data based on number of new building permits issued
Average Construction Site Size	Nominal value based on estimates of local Realtor
State and National Park Totals	The Outdoor Atlas and Recreation Guide 1992

6.0 MODEL EXECUTION

To run OECert, several key pieces of information must be obtained. The information needed for a dispersed site include the following items: hazard type; degree of slope; vegetation type; presence of slippery ground cover; percentage of UXO on the surface; sector UXO and total item density; weighted average of UXO weights; soil type; sector acreage; presence of bees, nakes, and poisonous foliage; presence of archaeological activity; presence of environmentally sensitive plants and wildlife; fencing required; number of guards needed and knowledge of which activities occur at the site.

For a localized site the following information is needed: hazard type, degree of slope, vegetation type, presence of slippery ground cover, area of hazard, maximum line of sight distance surrounding the hazard, excavation volume, area to be reconstituted, environmental factors, sifter requirement, fencing required, number of guards needed, knowledge of which activities occur at the site, OE removal volume, area to be prepared for clearance, and area of original site.

The model outputs from OECert will consist of a list sites prioritized by risk, cost, or cost-effectiveness ratio. The prioritized list may consist of any subset of the sites present in the database at the time of analysis. Additionally, detail risk estimates are provided at a "per activity" level, as well as life cycle cost estimates.

7.0 FUTURE USAGE

In the future, OECert will be expanded to handle many of the challenging issues pertaining to ordnance remediation. In addition to site prioritization based on cost-effectiveness, the following applications will be available.

7.1 Defacto Risk Standard Density

Defacto risk standards are being developed to determine when a site has been cleaned to an acceptable level. To develop these standards, the post-remediation risk is being measured at sites that have been cleaned to an acceptable level for their current land usage. These defacto standards will be based on the following definitions of risk: (1) the probability of exposure to ordnance for one person during a single site visit, and (2) the expected number of exposures to the surrounding population annually. In the future, OECert will accept a risk standard as input and compute the corresponding post-remediation ordnance density that must be achieved in order to meet the defacto risk standard.

7.2 Remediation Planning Tool

A remediation planning tool is being developed so that the project managers of formerly used defense sites may assess site remediation alternatives. These alternatives are base on : (1) a specified level of work performed, (2) a specified cost of remediation or (3) a specified residual risk. The tool is intended to assist im making level of remediation versus cost of remediation decisions.

A specified level of work is defined to be the clearance of UXO to a specified depth assuming some achieved sweep efficiency. Sweep efficiency is the portion of anomalies detected and removed in the clearance action. A specified cost is defined to be the remediation cost associated with clearance of UXO to some combination of level of work (clearance depth) and sweep efficiency which will result in the specified dollars. A specified risk is defined to be the probability of exposure (for an individual at a FUDS) associated with clearance of UXO to some combination of level of work (clearance depth) and sweep efficiency which will result in the specified residual risk.

7.3 Summary

The quantification of OE contamination is a necessary and prudent part of the management of sites which have been used by our armed forces. The quantification is necessary to communicate with the public and to plan remediation activities. A continued evolution of the OECert methodology will serve as a foundation for difficult future decisions concerning the allocation of scarce resources to very sensitive issues of great public concern.